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Green Chemistry Innovations for Sustainable Industrial Processes in India: Empirical Evidence from SMEs and Corporates

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Abstract

Green chemistry has emerged as a pivotal approach to reconcile industrial growth with environmental sustainability in India. This research paper analyses the adoption, drivers, barriers, and impacts of green chemistry innovations within the Indian chemical industry using publicly available data from corporate sustainability reports, government publications, and industry associations. The study evaluates solvent-free synthesis, biocatalysis, and catalytic process optimization in pharmaceutical, agrochemical, and specialty chemical sectors. Findings indicate regulatory pressure, cost savings, and export competitiveness drive adoption, while high upfront investment and technical skill gaps remain challenges. Documented evidence shows environmental benefits including reductions in energy consumption (15–35%), waste generation (20–50%), water use (25–45%), and greenhouse gas emissions. Evidence-based recommendations are provided for accelerating India's transition toward a green, competitive, and circular chemical industry.

Keywords: *Green chemistry; sustainable manufacturing; Indian chemical industry; biocatalysis; solvent-free synthesis; policy frameworks.*

Introduction

India ranks among the world's leading chemical-producing nations, contributing approximately 3–5% to national GDP [1]. Traditional chemical manufacturing remains resource-intensive, generating substantial hazardous waste and emissions [2]. Green chemistry provides a scientifically robust framework for sustainable industrial development, emphasizing waste prevention, atom economy, and catalysis [3]. In India, initiatives such as the National Mission on Sustainable Chemistry (NMSC) and Zero Liquid Discharge (ZLD) norms reflect growing emphasis on sustainable practices [4-6]. This study analyzes publicly available data to examine green chemistry adoption, environmental outcomes, drivers, barriers, and policy interventions needed for scaling adoption.

Methodology

A systematic document analysis was conducted using:

1. Corporate Sustainability/ESG Reports (2020-2024)
2. Government and Regulatory Publications
3. Industry Association Reports
4. Academic and Research Institution Publications

Data were collected through database searches, screened for relevance (2020-2024), extracted using standardized templates, and validated through cross-referencing. The analysis covers pharmaceutical, agrochemical, dye/pigment, and specialty chemical sectors.

Documented Adoption and Implementation

Pharmaceutical Sector

- **Dr. Reddy's Laboratories** implemented biocatalytic processes, reducing solvent usage by 30-40% and improving yields by 15-20% [7].
- **Sun Pharmaceutical Industries** replaced stoichiometric reagents with catalytic alternatives, eliminating approximately 500 tonnes of metallic waste annually [8].
- **Cipla Limited** adopted water-based reaction systems, reducing organic solvent consumption by 35% and wastewater treatment costs by 25% [9].
- 68% of large pharmaceutical firms have adopted green chemistry practices vs. 32% of SMEs [10].

3.2 Agrochemical Sector

- **UPL Limited** implemented continuous flow chemistry, achieving 30% energy savings and 45% reduction in wastewater [11].

- **Rallis India** optimized catalytic processes, increasing atom efficiency from 45% to 78% [12].
- **Dhanuka Agritech** documented solvent recovery systems achieving 85% recovery rates [13].

Dye and Pigment Industry

- Units in Gujarat's Ankleshwar cluster implemented solvent-free mechanochemical processes, eliminating 150-200 tonnes of solvent waste annually [14].
- Catalytic oxidation replaced stoichiometric oxidants, reducing heavy metal waste by 60-70% [15].
- Water-based pigment dispersion technologies reduced VOC emissions by up to 90% [16].

Specialty Chemicals

- **Tata Chemicals** implemented microwave-assisted reactions, reducing energy consumption by 40% and reaction time by 60% [17].
- **Aarti Industries** adopted enzymatic processes, improving selectivity from 85% to 98% [18].

Table 1. Documented Environmental Benefits (2020-2024)

Sector	Energy Reduction	Waste Reduction	Water Savings	GHG Reduction
Pharmaceuticals	15-30%	20-45%	25-40%	20-35%
Agrochemicals	20-35%	25-50%	30-45%	25-40%
Dyes & Pigments	10-25%	30-60%	20-35%	15-30%
Specialty Chemicals	25-40%	15-35%	15-30%	20-35%

Economic and Market Outcomes

- **Payback Periods:** 2-5 years for green chemistry investments
- **Operating Cost Reduction:** 15-30% through resource efficiency
- **Export Advantage:** 20-30% better market access with green certifications
- **Digital Integration:** AI, IoT, and digital twins emerging as enablers

Drivers and Barriers

Primary Drivers

1. Regulatory Pressure (ZLD norms, emission standards)
2. Economic Incentives (cost savings, subsidies)
3. Market Forces (export requirements, investor expectations)
4. Strategic Positioning (brand enhancement)

Persistent Barriers

1. Financial Constraints (high upfront investment)
2. Technical Challenges (limited expertise, scale-up facilities)
3. Regulatory Hurdles (approval delays, compliance complexity)
4. Market Barriers (price competition, limited awareness)

Policy Assessment

- **NMSC Strengths:** Research funding, awareness creation
- **NMSC Gaps:** Limited industry adoption, weak SME support
- **State Initiatives:** Gujarat, Maharashtra, and Tamil Nadu have specific green chemical policies

Recommendations

Policy Interventions

1. Green chemistry tax credits and low-interest loans for SMEs
2. Regional scale-up and technology demonstration centers
3. Fast-track approvals for green processes
4. Green public procurement and eco-labeling

Industry Actions

1. Strengthen industry-academia R&D partnerships
2. Implement standardized sustainability metrics
3. Adopt digital tools (AI, IoT) for process optimization
4. Develop in-house green chemistry training programs

Research and Education

1. Integrate green chemistry in chemical engineering curricula
2. Focus on scalable, cost-effective solutions for Indian conditions
3. Create open-access databases of best practices

Financial Sector Engagement

1. Develop dedicated green financing instruments
2. Include green chemistry metrics in ESG frameworks
3. Create sustainability performance assessment tools

Conclusion

This analysis demonstrates significant progress in green chemistry adoption across India's chemical industry, with documented environmental benefits including energy savings (15-40%), waste reduction (20-60%), water conservation (25-45%), and GHG emission reductions (15-40%). Large corporates lead implementation, while SMEs require targeted support. Digital integration represents a promising frontier for enhancing efficiency. Policy interventions should create enabling ecosystems addressing financial, technical, and regulatory challenges. Green chemistry offers a viable pathway for transforming India's chemical sector into a driver of circular economy and sustainable development.

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Conflicts of interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

References

1. Ministry of Chemicals and Fertilizers. (2024). Annual Report 2023-2024.
2. CPCB. (2023). Environmental Performance of Chemical Industries in India.
3. Anastas, P. T., & Warner, J. C. (1998). Green Chemistry: Theory and Practice.
4. NMSC. (2023). Progress Report 2022-2023.
5. CPCB. (2022). Zero Liquid Discharge: Implementation Status.
6. Ministry of Commerce and Industry. (2024). PLI Scheme for Advanced Chemicals.
7. Dr. Reddy's Laboratories. (2023). ESG Report 2023.
8. Sun Pharmaceutical Industries. (2024). Sustainability Disclosure Report.
9. Cipla Limited. (2023). ESG Performance Report.
10. IDMA. (2023). Green Chemistry Adoption Survey Report.
11. UPL Limited. (2024). ESG Report.
12. Rallis India. (2023). Sustainability Report.
13. Dhanuka Agritech. (2023). Annual Report 2022-2023.
14. CMAI. (2024). Sustainable Practices in Dye Industry.
15. GPCB. (2023). Best Practices in Chemical Industry.
16. MSME Ministry. (2023). Green Technology Adoption in SMEs.
17. Tata Chemicals. (2023). Sustainability Report 2023.
18. Aarti Industries. (2024). ESG Disclosure Report.